Technologies for Distributed Energy Resources

Increases in electric power demand and the need for greater system reliability are driving the development and use of distributed power generation systems

Distributed energy resources, or DER, are small, modular, decentralized, grid-connected or off-grid power-generating systems located in or near the place where energy is used. These integrated power systems can include effective means of energy storage and delivery as well as power-generating technologies. DER systems can help to meet increased demand, reduce peak operating costs, and improve the reliability of the electric power generation system. Coupling DER systems with energy efficiency measures and good energy management practices can make them even more effective.

Thousands of grid-connected and off-grid DER systems are being used today at many kinds of Federal government facilities, including office buildings, national park facilities, and employee housing. They can provide continuous electric power, backup power, or supplemental power during times of peak demand.

Andrew Gordon Photography/Fox & Fowle Architects/PIX09052

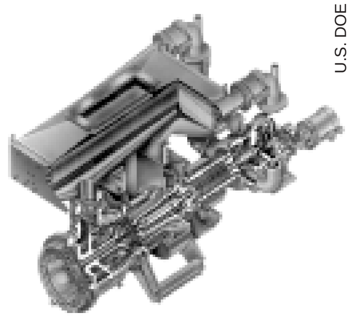
The photovoltaic “skin” on the top 14 floors of this building in New York's Times Square produces electricity from sunlight.

The U.S. Department of Energy (DOE) works with both public and private partners to develop and advance these power-generating systems. Through DOE’s Federal Energy Management Program (FEMP), agencies can explore opportunities to use these existing and emerging technologies to help decrease costs and increase system reliability:

- Advanced industrial turbines and microturbines
- Combined heat and power (CHP, or cogeneration) systems
- Fuel cells
- Geothermal systems
- Natural gas reciprocating engines
- Photovoltaics and other solar systems
- Wind turbines
- Small, modular biopower
- Energy storage systems
- Hybrid systems.

Advanced Industrial Turbines and Microturbines

Combustion turbines are electricity-generating devices that produce high-temperature, high-pressure gas; the gas impinges on a series of specially designed blades to rotate the turbine shaft. Many turbines also use a heat exchanger (or recuperator) so that exhaust heat from the turbine can also be used.



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Gases derived from coal, biomass, and hydrocarbon gasification can be used in some advanced industrial turbines.

The high-quality steam that these turbines generate can be used in combined-cycle or combined heat and power applications, enhancing efficiency. Maintenance costs per unit of power output are among the lowest of all the power-generating technologies.

Capstone Turbine Corp./PIX08131

This microturbine is essentially a gas-fired jet engine attached to a high-speed electrical generator.

Microturbines are small combustion turbines with outputs of 25 to 1,000 kilowatts (kW). Microturbines evolved from automotive and truck turbochargers, auxiliary power units for airplanes, and small jet engines. Microturbines do not require oil changes, spark plug changes, or valve adjustments and can last a long time. Microturbine systems can be 25% to 30% efficient, and emissions are much lower than those of conventional turbines or reciprocating engines. They currently cost around \$1,100/kW; future costs of next-generation systems are expected to be even lower.

Technical Assistance

U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy

Combined Heat and Power

Combined heat and power (CHP), or cogeneration, involves capturing waste heat from power production and putting it to use at the customer's site. Future CHP systems could achieve greater than 90% fuel utilization efficiency in industrial, commercial, and residential applications. CHP combines a "prime mover" system such as a combustion turbine, reciprocating engine, or fuel cell with waste heat recovery equipment to produce hot water, steam, cooling, and mechanical energy and to regenerate desiccants for humidity control.

David Parsons/PIX05815

A conventional cogeneration system is the basis for this recycling/energy recovery pilot plant in California.

Large-scale CHP systems are used in the pulp and paper, chemical manufacturing, and petroleum refining industries. Smaller power generation systems are creating opportunities for CHP in other manufacturing industries and in commercial buildings. In certain settings, waste heat can be used for hot water or steam that circulates through pipes to several thermal energy users. These district energy systems are highly cost-effective.

Fuel Cells

Power is produced in fuel cells electrochemically by passing a hydrogen-rich fuel over an anode and air over a cathode and separating the two by an electrolyte. The by-products are usually only heat, water, and carbon dioxide. Fuels cells are highly efficient and quiet, and they can be stacked to obtain a usable voltage and power output and to match specific power needs.

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Fuel cells are being developed for stationary power applications as well as for transportation.

Hydrogen fuel is produced by subjecting hydrocarbon resources, such as natural gas, to steam under pressure (known as reforming or gasification). This process often requires combustion and results in environmental emissions. Processes that do not involve combustion are being developed.

Phosphoric acid fuel cells (PAFCs) are in the market entry phase and cost around $4,000/kW. More than 200 PAFC units, most about 200 kW in size, have been sold worldwide. Molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC) are featured in full-scale demonstrations; proton exchange membrane (PEM) fuel cells are in early development and testing phases. Fuel cells are integrated with an inverter to convert direct current to alternating current; in some cases, waste heat can be used for a site's thermal energy requirements.

Geothermal Systems

Both geothermal power plants and geothermal heating and cooling systems can be suitable for some DER applications. Where geothermal resources are available, the natural heat of the earth's interior drives a turbine generator to produce electricity. Geothermal heating and cooling systems—geothermal heat pumps—can be used with different building types in many parts of the country.

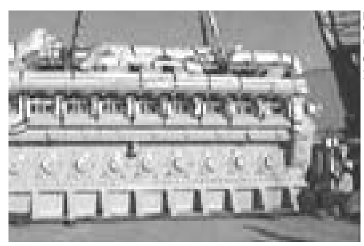
David Parsons/PIX01045

The Geysers in California is the largest geothermal plant in the world; it can produce 750 MW of electric power.

Using the steady underground temperatures of the earth, geothermal heat pumps warm air during the heating season and cool it during the cooling season. They can also be used to heat water. Geothermal heat pumps for commercial buildings can significantly reduce energy consumption and peak demand. Although first costs can be higher than those of other heating and cooling systems, geothermal heat pumps can be life-cycle cost-effective because they reduce energy use and operations and maintenance costs in the long term. They also improve comfort levels in many facilities.

Natural Gas Engines

The reciprocating engine is a widespread, well-known technology. Spark ignition gas-fired units typically use natural gas or propane. Capacities are typically 0.5–5 MW but can range up to 10 MW.



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This large reciprocating engine generates power at the University of Alaska, Fairbanks.

Reciprocating engines, costing around $500/kW, are the least expensive DER systems available today. They feature easy start-up, proven reliability, good load-following characteristics, and good heat-recovery potential. The majority are diesel-fired, internal combustion engines; cleaner natural gas and dual-fuel engines are being developed. Converting a diesel engine to dual-fuel can cost $20/kW or more but can significantly reduce emissions. In the future, this standard power supply technology could operate on renewable biomass fuels.

Photovoltaics and Other Solar Systems

Photovoltaics (PV) and other solar systems can be used in many parts of the country. PV systems use semiconductor-based solar cells connected in modules to convert sunlight directly to electricity. They are quiet, have no or few moving parts, and do not generate emissions while operating. Most commercial modules are made of crystalline or thin-film silicon materials. PV systems can generate electricity on almost any scale. Current average capital costs, which have fallen 50% since 1991, range from $5 to $10/W, and worldwide annual sales were about 280 MW in 2000.

Federal Facilities Can Use Various DER Technologies to Meet Different Electric Power and Thermal Needs

	Applications				
System Types	Improved Power Quality	Standby Power	Peak Shaving	Low-Cost Power	Combined Heat and Power
Advanced Industrial Turbines and Microturbines		✔	✔	✔	✔
Fuel Cells	✔			✔	✔
Geothermal Systems			✔		✔
Natural Gas Engines		✔	✔	✔	✔
Photovoltaic Systems*		✔	✔		
Wind Energy Systems*			✔	✔	
Small Modular Biopower Systems		✔	✔	✔	✔
Energy Storage Systems	✔	✔			
Hybrid Systems	✔	✔	✔	✔	✔

Notes on the applications:

Improved Power Quality—these DER systems (usually UPS, other storage, or hybrids) allow energy users to ride through short-term outages of a few minutes or less.

Standby Power—these provide readily dispatchable backup power during longer outages.

Peak Shaving—these provide power for high-demand periods, eliminating excessive demand or time-of-use charges and helping to avoid community-wide shortages.

Low-Cost Power—these systems usually operate continuously in baseload mode, reducing electric energy costs by providing electricity for a facility.

Combined Heat and Power—these provide both baseload electric power and heat for facility needs or process applications.

*Standby power and peak-shaving applications depend on facility load profiles and whether batteries are used.

Source: Joseph Iannucci, Distributed Utility Associates, February 2001; Lynne Gillette, Office of Solar Energy Technologies, March 2001.

U.S. DOE/Craig Miller Productions/PIX02149

A rooftop solar thermal system and a PV system provide heat and electricity to an Olympic swimming pool building in Atlanta.

Though not currently considered a dispatchable power source, PV systems can be well-suited to peak-load-shaving applications because of their excellent load-matching characteristics; at many Federal facilities, the greatest requirement for energy occurs when the solar resource is at its highest intensity. With building-integrated photovoltaics, or BIPV, power is generated by a specially designed PV building component, such as an awning, skylight, wall, or roofing material.

Karen Atkison/PIX07756

A solar concentrating trough system heats water for a prison in Arizona.

Solar water heating systems can provide peak-load shaving in facilities that use large amounts of hot water, such as prisons, hospitals, dormitories, and cafeterias. Solar systems can be highly cost-effective in areas with good solar resources. Flat-plate solar collector systems are the most common types. Concentrating solar systems use sun-tracking mirrors to reflect and concentrate sunlight onto a receiver, where the light is converted to high-temperature thermal energy. The three types of concentrating solar technologies being developed are parabolic troughs, dish/engines, and power towers. Troughs can be very appropriate for facilities using a lot of hot water.

Wind Energy Systems

Warren Gretz, NREL/PIX08698

Wind turbines on San Clemente Island, California, provide power for the U.S. Navy.

Wind turbines convert the kinetic energy of the wind into electricity. Most wind machines have two or three propeller-like blades mounted on a rotor connected to an electric generator that is typically 0.5–1 MW in capacity. Larger turbines are now entering the commercial marketplace.

Wind energy systems are modular and can be clustered in areas with good wind resources. For distributed energy generation, a small number of turbines can be sited on Federal land to power government facilities, such as those in national parks. Wind systems in this size range currently cost around $1,000/kW or more. Approximately 16,000 wind systems are operating in the United States today.

Small Modular Biopower

Community Power Corp./PIX09103

A proof-of-concept small modular biopower system is demonstrated at DOE's National Renewable Energy Laboratory.

When plants, trees, and organic waste—biomass—are burned, they produce heat. In power plants, this heat is captured by boiling water to generate steam, which turns turbines and drives generators that convert the energy into electricity. New technologies now being evaluated include several types of biomass gasifiers, in which biomass is heated to convert it into a gas. The gas is used directly in a turbine that drives a generator. In some cases, the waste heat from the gas turbine may also be used to drive a secondary steam turbine, converting more of the fuel energy into electricity in a combined-cycle system.

Gasification provides flexibility, in both the range of possible biomass feedstocks and the end use of the energy. For example, gas from a gasifier can power a fuel cell to generate electricity as well as drive a steam turbine. Large steam turbine systems in power plants of 200 MW or more are relatively efficient at energy conversion.

Biomass gasification systems should soon be able to combine high efficiency with cost-competitiveness in smaller sizes. Small modular biomass conversion (biopower) systems (100 kW-5 MW) are being developed that may soon provide cost-effective electricity to Federal facilities.

Energy Storage Systems


Warren Gretz, NREL/PIX02140

A 50-kW battery storage system is tested in Colorado.

Uninterruptible power supply (UPS) systems may be the most widely used and best-known energy storage systems for DER applications. UPS systems provide high-quality power to facilities that cannot tolerate even brief outages. Batteries are the most common energy storage devices, but not the only ones. Flywheels, superconducting technologies, ultracapacitors, and supercooled electromagnets are also possible storage devices. Energy storage systems are often one component of hybrid DER systems, and they can make the power from otherwise nondispatchable energy sources available when it's most needed.

Hybrid Systems

Hybrid systems consist of two or more types of distributed energy technologies. The separate units are integrated into packaged hybrid systems that can improve the array of energy services provided to customers. Several different concepts are being developed.


Northern Power Systems/PIX08954

A hybrid wind/PV/diesel system powers a research station in Antarctica for the National Science Foundation.

One is the CHP or combined heat and power system. This hybrid system combines power generation, heating, cooling, and humidity control systems into a packaged unit for commercial, industrial, and district energy users, as noted earlier.

Another hybrid concept involves the integration of fuel cells and gas turbines. This type of system has potentially higher efficiencies and lower emissions than the individual systems have separately. Efforts to develop next-generation turbine systems include integrating special engine systems with fuel cells to produce all-hybrid configurations.

Fossil/renewable hybrid systems combine the best of two worlds; they feature lower emissions for fossil power production and continuous power for times when renewable resources are not available. They work by coupling fossil generation units with wind or solar power-generating systems and, when possible, battery storage. When the sun is shining or the wind is blowing, the energy generated by the renewable system can either be provided to users or used to charge a battery storage system.

For More Information

FEMP Help Desk: 800-DOE-EREC (363-3732)

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